Bifenthrin Criteria Derivation
DRAFT

Amanda J. Palumbo, Tessa L. Fojut, Ronald S. Tjeerdema

Environmental Toxicology Department, University of California – Davis
Davis, CA

1. Introduction

A new methodology for deriving freshwater water quality criteria for the protection of aquatic life was developed by the University of California, Davis (TenBrook *et al.* 2009a). The need for a new methodology was identified by the California Central Valley Regional Water Quality Control Board (CVRWQCB 2006) and findings from a review of existing methodologies (TenBrook & Tjeerdema 2006, TenBrook *et al.* 2009b). This new methodology is currently being used to derive aquatic life criteria for several pesticides of particular concern in the Sacramento River and San Joaquin River watersheds. The methodology report contains an introduction (Chapter 1); the rationale of the selection of specific methods (Chapter 2); detailed procedure for criteria derivation (Chapter 3); and a chlorpyrifos criteria report (Chapter 4). This criteria report for bifenthrin describes, section by section, the procedures used. Also included are references to specific sections of the methodology procedure detailed in Chapter 3 of the report so that the reader can refer to the report for further details (TenBrook *et al.* 2009a).

2. Basic Information

Chemical: Bifenthrin (Fig. 1)
CAS: (2-methyl[1,1'-biphenyl]-3-yl)methyl (1*R*,3*R*)-rel-3-[(1*Z*)-2-chloro-3,3,3-trifluoro-1-propenyl]-2,2-dimethylcyclopropanecarboxylate
IUPAC: 2-methyl-3-phenylbenzyl (1*RS*)-cis-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate

Chemical Formula: $C_{23}H_{22}ClF_3O_2$

CAS Number: 82657-04-3
CA DPR Chem Code: 2300

Trade names: Bifenthrin, bifenthrine, Bifentrin, Bifentrina, Biflex, Biphenthrin, Brigade, Capture, Cyclopropanecarboxylic acid, FMC 54800, FMC 54800 Technical, Talstar, Tarstar, DeterMite, Biphenate, Torant (with Clofentezine), Zipak (with Amitraz) (Kegley *et al.* 2008, FMC Corp. 2007, EXTOXNET 1995)

Classification: EPA Class C Carcinogen (EXTOXNET 1995)

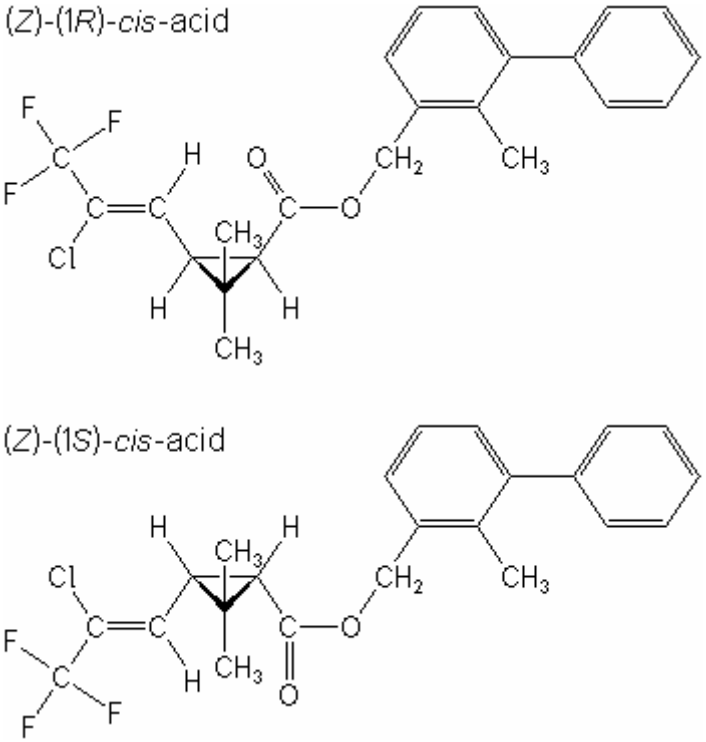

Figure 1. Structure of bifenthrin and stereoisomers (Wood 2008)

3. Physical-Chemical Data

Molecular Weight
422.87 (Laskowski 2002, EXTOXNET 1995)

Density
1.26 g/mL (FOOTPRINT 2008)
1.212 g/mL at 25^{o}C (Meister 2002)

Water Solubility
100 µg/L (Kidd & James 1991)
2.5 µg/L (FOOTPRINT 2008)
0.014 µg/L (Laskowski 2002)

Melting Point
Liquid at room temperature
68-70.6 ^{o}C (EXTOXNET 1995)
69.3 ^{o}C (FOOTPRINT 2008)

Organic Carbon-Water Adsorption Coefficient (K_{oc})
6,314 (Kegley *et al.* 2008)
237,000 (Laskowski 2002)
380,000- 980,000 (Xu *et al.* 2007)
236,610 (FOOTPRINT 2008)

$1.1x10^5$(9d equilibrium), 7.0×10^5(30d equil.), both freshwater (Bondarenko *et al.* 2006)
2.6×10^5 (9d equilibrium), 2.7×10^5 (30d equil.), both marine (Bondarenko *et al.* 2006)

Logistic Octanol-Water Partition Coefficient (Log K_{ow})
6.00 (Hansch *et al.* 1995, recommended by Sangster Research Laboratories 2007)
5.56 using HPLC (Donovan & Pescatore 2002)
6.4 (Laskowski 2002)
6.0 at 20 ^oC calculated (FOOTPRINT 2008)

Dissociation Coefficient (K_d)
390 (Surprenant 1988)
9,300- 18,900 (Xu *et al.* 2007)
1,400-15,100 (Yang *et al.* 2006a)
8,600-24,400 (Yang *et al.* 2006b)

Vapor Pressure
1.80E-07 mm Hg at 25^oC (Tomlin 1994, Laskowski 2002)
1.81E-07 mm Hg at 25^oC (Meister 2002)

Henry's Constant (K_H)
7.2×10^{-3} atm m^3 mol^{-1} (Laskowski 2002)
1.2×10^2 Pa m^3 mol^{-1}, at 25 ^oC (FOOTPRINT 2008)
4.10×10^{-2} dimensionless, at 20 ^oC (FOOTPRINT 2008)

Half-life

anaerobic soil degradation:	425 d (Laskowski 2002)
anaerobic soil degradation:	179.5 d (Kegley *et al.* 2008)
aerobic soil degradation:	96 d (Laskowski 2002)
aerobic soil degradation:	123.0 d (Kegley *et al.* 2008)
sediment:	8-17 mo at 20^oC (Gan *et al.* 2005)
soils:	44-47 mo at 25^oC (Baskaran *et al.* 1999)
hydrolysis:	stable (Laskowski 2002)
photolysis, water:	408 d (Laskowski 2002)
photolysis, soil:	96.9 d (Laskowski 2002)

Bioconcentration Factors

Table 1. Bioconcentration factors (BCF) for bifenthrin; FT: flow-through; S: static; R: Recirculating. Values are on a wet weight basis and are not lipid normalized.

Species	**BCF**	**Exposure Type**	**Reference**
Lepomis machrochirus[1]	6090	FT, 42 d	Surprenant 1986
Lepomis machrochirus[2]	8720	FT, 42 d	Surprenant 1986
Lepomis machrochirus[3]	2140	FT, 42 d	Surprenant 1986
Pimephales promelas[1]	21,000-28,000	FT, Life Cycle	McAllister 1988
Pimephales promelas[4]	83-4900	FT, Life Cycle	McAllister 1988
Pimephales promelas[5]	530-10,000	FT, Life Cycle	McAllister 1988
Pimephales promelas[6]	6000	FT	McAllister 1988

Pimephales promelas	45-63	R, 21 d	Surprenant 1988
Daphnia magna	~ 1000-4600	S, 24 h	Yang *et al.* 2006a
Daphnia magna[7]	~ 1200-2600	S, 24 h, w/ sediment	Yang *et al.* 2006a
Daphnia magna	270-440	R, 21 d	Surprenant 1988
Asellus sp.	71-82	R, 21 d	Surprenant 1988
Asellus sp.	120-180	R, 21 d, w/ soil	Surprenant 1988
Corbicula	41-74	R, 21 d	Surprenant 1988
Corbicula	92-140	R, 21 d, w/ soil	Surprenant 1988

[1]whole body, [2]viscera, [3]fillet, [4]<48h embryos, [5]96h embryos, [6]14d larvae, [7] with suspended solids (0-200 mg/L)

4. Mode of Action and Toxicity

Pyrethroids affect the nervous system and induce paralysis in insects. More specifically, these compounds prevent sodium and potassium channels in the neuronal membranes from closing, causing over-excitation of neurons. The site of toxic action is very similar to that for DDT (Miller & Salgado 1985). Aquatic organisms are inherently more sensitive to pyrethroid pesticides than their terrestrial counterparts (Siegfried 1993), due to the effect of pyrethroids on Na^+ ATPase, an enzyme crucial to osmoregulation (Clark & Matsumura 1981).

Pyrethroids are chiral compounds consisting of multiple stereoisomers. The commercial formulations of bifenthrin are made up of 1*R*-*cis*-BF and 1*S*-*cis*-BF isomers (Figure 1). The 1*R*-*cis* enantiomer was the only enantiomer in *cis*-BF showing acute toxicity against *Ceriodaphnia dubia* (Liu *et al.* 2005). Additionally, it was found that the 1*S*-*cis* enantiomer was preferentially degraded over the 1*R*-*cis* enantiomer, so the more toxic isomer was also more persistent in this case (Liu *et al.* 2005).

In addition to acute toxicity, pyrethroids can induce sublethal toxicity such as altered behavior, reduced growth, immune system effects, endocrine reproductive effects, histopathological effects, as well as biochemical responses. Such sublethal effects may cause changes in predation avoidance, competition, learning and other characteristics that can affect survival and reproductive success (Werner & Moran 2008). Direct links of these effects to survival are difficult to establish. However, these effects likely contribute to negative effects on survival, growth, or reproduction, which are measured in standard chronic toxicity tests. Solomon *et al.* (2001) compiled toxicity data available for several pyrethroids and found acute to chronic ratios (ACRs) of 2 - 425 for pyrethroids in a variety of species. The large ACRs were not just for fish. Using the data for *Daphnia magna*, calculated ACRs for cypermethrin, tralomethrin, and lambda-cyhalothrin were around 100, while those for cyfluthrin, fenvalerate/esfenvalerate, permethrin, and fenpropathrin were around 5. Chronic toxicity data for sensitive species is needed to derive fully protective criteria for pyrethroids.

5. Environmental and Metabolic Fate

Bifenthrin, a third-generation synthetic pyrethroid, has greater photostability and enhanced insecticidal activity in comparison to older formulations (Mokry & Hoagland

1990). Bifenthrin is non-polar and has a strong affinity for soil particles and organic matter as represented by its high organic carbon-water adsorption partition coefficient (K_{OC}; see section 3). The strong sorption to soils and the low water solubility would seem to confine these compounds to areas of use. However, they are able to move with runoff into surface streams by moving with suspended sediments and dissolved organic matter (Weston *et al.* 2004, Gan *et al.* 2005). The toxicity of pyrethroids to wildlife may be mitigated by their high affinity for suspended particulates (Muir *et al.* 1985, Hill 1989), and likewise toxicity during laboratory testing may be reduced due to surface adherence (Froelich *et al.* 1984).

A study of bifenthrin and three other pyrethroids by Bondarenko *et al.* (2006), which examined the time-dependence of pyrethroids distributed in the freely dissolved, dissolved organic matter (DOM), and solid phases, found only a small percentage of these compounds in the freely-dissolved portion of several samples. In addition, there was a significant difference between the amount of freely-dissolved bifenthrin in the sample after 9 days, when compared with the same fraction after 30 days, suggesting that bifenthrin takes a long time to reach equilibrium within an aquatic system (Bondarenko *et al.* 2006).

Bifenthrin is stable in water and has a relatively long half-life in soils and sediments (see values in section 3). Long persistence was observed for bifenthrin under both aerobic and anaerobic conditions, and the half-life ranged from 8 to 17 months at 20°C (Gan *et al.* 2005). Although pyrethroids are prone to breakage at their ester linkage (Bradbury & Coats 1989, Tyler *et al.* 2000), upon binding to particulate matter the microbial degradation slows significantly and the half-life increases (Lee *et al.* 2004).

6. Human and Wildlife Dietary Values

There are no FDA action levels for bifenthrin (USFDA 2000). There are no food tolerances for fish, but there are food tolerances for meat of cattle, goat, hogs, horses, and sheep at 0.5 ppm (USEPA 2006c).

Wildlife LC_{50} values (dietary) for animals with significant food sources in water

For mallard ducklings an eight day dietary LC_{50} value was 1280 mg/kg feed (Fletcher 1983a). No ducklings died from the lowest dose, the 312 mg/kg feed, but these ducklings weighed less than the control ducklings. An acute study that monitored ducks for 21 days after a single dose found no effects. Using the highest dose the NOEC would be 2150 mg/kg body weight for adult mallards (Fletcher 1983b). No indication of reproductive impairment was observed in mallards after eating a diet spiked with 25 - 75 mg/kg feed (Roberts *et al.* 1986).

7. Ecotoxicity Data

Approximately 40 original studies on the effects of bifenthrin on aquatic life were identified and reviewed. In the review process, many parameters are rated for

documentation and acceptability for each study, including, but not limited to: organism source and care, control description and response, chemical purity, concentrations tested, water quality conditions, and statistical methods (see Tables 3.6, 3.7, 3.8 in TenBrook *et al.* 2009a). Single-species effects studies that were rated relevant (R) or less relevant (L) according to the method were summarized in the data summary sheets. Information in these summaries was used to evaluate each study for reliability using the rating systems described in the methodology (section 3-2.2, TenBrook *et al.* 2009a). Copies of completed summaries for all studies rated reliable and relevant (RR) for criteria derivation are included in Appendix A of this report. Bifenthrin studies deemed irrelevant from an initial screening were not summarized (e.g., studies involving rodents or *in vitro* exposures). All data rated as acceptable or supplemental for criteria derivation are summarized in Tables 2 - 6 found at the end of this report.

Using the data evaluation criteria (section 3-2.2, TenBrook *et al.* 2009a), nine acute toxicity studies, yielding thirteen toxicity values were judged reliable and relevant (RR) for criteria derivation (Tables 2 and 4). Ten studies were rated RL, LL, or LR and were used as supplemental information for evaluation of the derived criteria in Section 14 (Table 6).

Ten mesocosm, microcosm and ecosystem (field and laboratory) studies were identified and reviewed. Four of these studies were rated R or L and were used as supporting data in section 15 (Table 7). Three relevant studies of bifenthrin effects on wildlife were identified and reviewed for consideration of bioaccumulation in section 17.

8. Data Reduction

Multiple toxicity values for bifenthrin for the same species were reduced into one species mean acute toxicity value according to procedures described in the methodology (section 3-2.4, TenBrook *et al.* 2009a). Acceptable acute and chronic data that were excluded, and the reasons for their exclusion, are shown in Tables 3 and 5, respectively. Reasons for exclusion of data included: more sensitive endpoints were available for the same test and more appropriate or more sensitive test durations were available for the same test. The final acute and chronic data sets are shown in Tables 2 and 4, respectively.

9. Acute Criterion Calculation

At least five acceptable acute toxicity values were available and fulfilled the five taxa requirements of the species sensitivity distribution (SSD) procedure (section 3-3.1, TenBrook *et al.* 2009a). The five taxa requirements are a warm water fish, a cold water fish, a planktonic crustacean, a benthic crustacean, and an insect. The log-logistic SSD procedure was used for the acute criterion calculation because not more than eight acceptable acute toxicity values were available in the bifenthrin data set as seen in Table 3 (section 3-3.2.2, TenBrook *et al.* 2009a). The log-logistic SSD procedure was used to derive 5^{th} percentile values (median and 95% confidence limit), as well as 1^{st} percentile values (median value only, as the software could not provide a 95% confidence limit for the 1^{st} percentile).

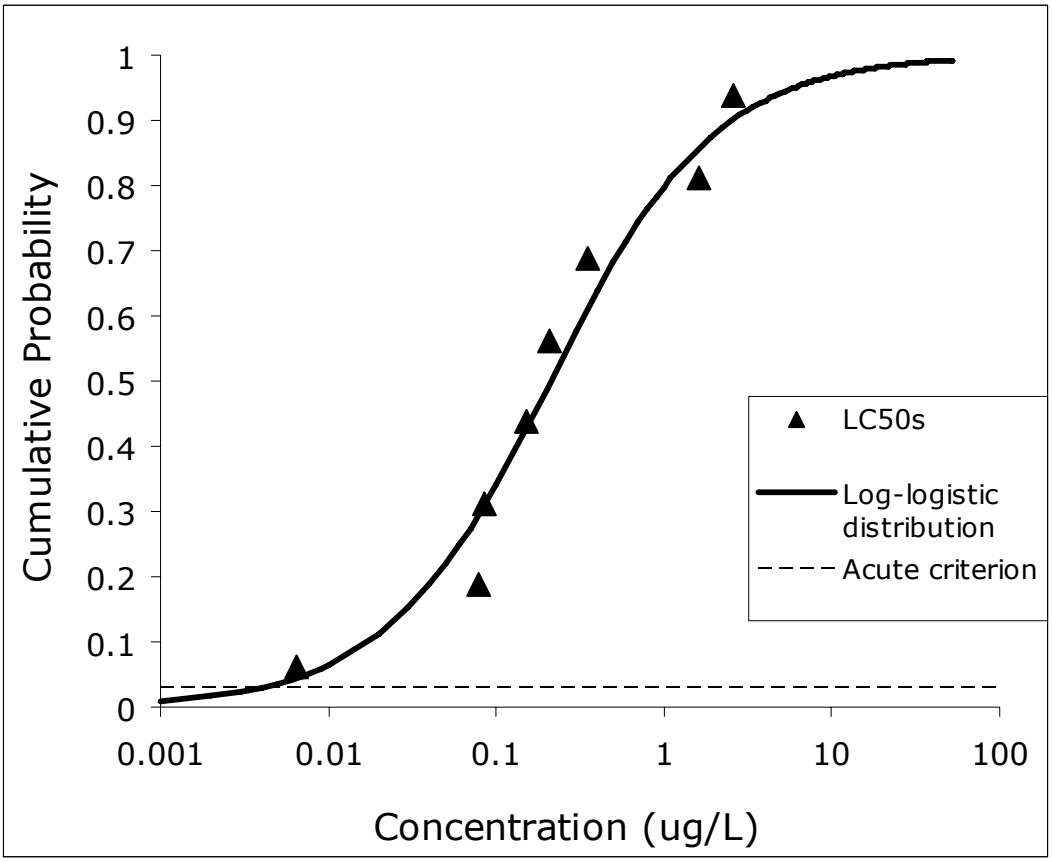

Figure 2. Bifenthrin acute data set fit to a log-logistic species sensitivity distribution.

The ETX 2.0 Software program (Van Vlaardingen *et al.* 2004) was used to fit the data set to a log-logistic distribution, which is plotted with the acute values in Figure 2. This distribution provided a satisfactory fit (see Appendix B) according to the fit test described in section 3-3.2.4 of TenBrook *et al.* (2009a). It can be seen that there is uncertainty in the first significant figure by comparing the 95% confidence limit to the acute criteria, thus final the criterion will be reported with one significant digit.

HC5 Fitting Parameter Estimates: α = -0.677, β (median) = 0.4925, β (lower 95% CI) = 0.9431.

5^{th} percentile, 50% confidence limit: 0.007460 µg/L
5^{th} percentile, 95% confidence limit: 0.0003516 µg/L
1^{st} percentile, 50% confidence limit: 0.001147 µg/L

Recommended acute value = 0.007460 µg/L (median 5^{th} percentile value)

Acute criterion = acute value ÷ 2 = 0.003730 µg/L = 3.7 ng/L
Acute criterion = 4 ng/L

10. Chronic Criterion Calculation

Chronic toxicity values from fewer than five different families were available, thus the acute-to-chronic ratio (ACR) method was used to calculate the chronic criterion. Two chronic toxicity values are in the acceptable (rated RR) data set (Table 4) satisfying two of the five taxa requirements (section 3-3.1, TenBrook *et al.* 2009a): warm water fish (*Pimephales promelas)* and planktonic crustacean (*Daphnia magna)*.

Neither of the above mentioned chronic toxicity values could be paired with an appropriate corresponding acute toxicity value in order to calculate an ACR. The acute toxicity value for *Pimephales promelas* was conducted using a static test, which is inappropriate for determining a fish ACR (section 3-4.2.1, TenBrook *et al.* 2009a). For the *Daphnia magna* chronic toxicity value, there was another test that contained an acute toxicity value, but this test does not provide an appropriate corresponding value for an ACR because the test was not performed in the same laboratory or in the same dilution water (section 3-4.2.1, TenBrook *et al.* 2009a).

Salt-water data in the supplemental data set (Table 6) contained acute and chronic toxicity values for a mysid (*Mysidopsis bahia)*, however the acute study was conducted in full seawater (30 ppt salinity), whereas the chronic studies were conducted in estuarine water (20 ppt salinity). These again are not appropriates corresponding toxicity values for an ACR, because the tests were not performed in the same dilution water (section 3-4.2.1, TenBrook *et al.* 2009a).

To avoid excessive layers of estimation, estimated chronic toxicity values using the Acute-to-chronic estimation software (ACE v. 2.0, USEPA 2003a.) were not derived to aid in calculating ACRs. Also, there were insufficient data to use this kind of estimation to produce chronic values for all five taxa that are required to construct a chronic SSD.

Because an ACR cannot be calculated with the available data, the chronic criterion was calculated with the default ACR value of 12.4 (section 3-4.2.3, TenBrook *et al.* 2009a). The chronic criterion was calculated using the acute criterion and the default ACR value as follows:

Chronic criterion = acute 5^{th} percentile value ÷ ACR = 3.730 ng/L ÷ 12.4 = 0.3008 ng/L
Chronic criterion = 0.3 ng/L

This value is approximately a factor of six below the lowest acceptable chronic value (MATC) of 1.9 ng/L for *Daphnia magna* (Table 4).

11. Bioavailability

Although bifenthrin and other pyrethroids are not very soluble in water, aquatic organisms are very sensitive to pyrethroids and toxicity does occur. Several ecosystem and field studies are reviewed in section 15 that point to bifenthrin as the cause of toxicity

in surface waters in the California Central Valley. This toxicity is believed to occur primarily from the portion of the compound that is dissolved in the water, not from the compound that is associated with the particulate phase (Amweg *et al.* 2005). Bioavailability of bifenthrin to organisms in the water column was also demonstrated by Surprenant (1988). Bifenthrin from spiked soil samples was available at concentrations sufficient to cause toxicity to aquatic organisms (such as *Daphnia magna)* that were housed in a separate container from the sediment, but shared the same recirculating water (however, there was no filtration to prevent dissolved particles from moving, so particles could have been involved in the exposure).

Several studies suggest that the binding of bifenthrin to suspended solids and dissolved organic matter will make the bound fraction unavailable and thus nontoxic to aquatic organisms. Yang *et al.* (2006a) found uptake of ^{14}C-labeled bifenthrin by *Daphnia magna* decreased with increasing suspended solids concentration, and that the organism uptake was closely mimicked by solid-phase microextraction (SPME) method using polydimethylsiloxane (PDMS) fibers. Regression analysis suggested that the portion of the pesticide sorbed to particles was unavailable to organisms in the 24-hour study period. In a complimentary study by Yang *et al.* (2006b), bifenthrin LC_{50} values for *Ceriodaphnia dubia* were five times higher when 200 mg/L of suspended sediment was added compared to the sediment-free tests. Xu *et al.* (2007) determined that the freely dissolved concentrations in the pore water (as measured by SPME) were the best predictor of toxicity to *Chironomus tentans* exposed to sediment spiked with bifenthrin. These studies suggest that the freely dissolved concentration will be the most accurate predictor of toxicity.

On the other hand, equilibrium partitioning would suggest that as organisms take up bifenthrin, more bifenthrin will desorb from particles, so the fraction absorbed to solids is likely not completely unavailable. Benthic organisms, such a *Hyalella azteca* may be at greater risk because of their exposure to pore water and close proximity to sediments. Additionally, the role of dietary exposure on bioavailability of pyrethroids has not been considered. In the test with *Ceriodaphnia dubia* and *Daphnia magna*, organisms were not fed during the test duration (Yang *et al.* 2006a, 2006b). Organisms living in contaminated waters are also ingesting food with sorbed hydrophobic compounds that can be desorbed by digestive juices (Mayer *et al.* 2001). The effects of dietary exposure may also be species-specific, depending on typical food sources; some species may have greater interaction with particles, increasing their exposure.

Section 3-5.1 of the methodology (TenBrook *et al.* 2009a) suggests that if studies indicate that fewer than three phases of the pesticide (sorbed to solids, sorbed to dissolved solids, or freely dissolved in the water) are bioavailable that compliance may be based on the concentration in the bioavailable phase(s). The studies above suggest that the freely dissolved fraction of bifenthrin is the primary bioavailable portion of bifenthrin, and that this concentration is the best indicator of toxicity. At this point, this recommendation is not being made for compliance assessment, but it is useful to consider how the freely dissolved concentration can be determined and how these methods compare to analytical methods used in toxicity test.

The most direct way to determine compliance would be to measure the bifenthrin concentration in the dissolved phase to determine the total bioavailable concentration. SPME has shown to be the best predictor of toxicity in several studies (Bondarenko *et al*. 2007, Hunter *et al.* 2008, Xu *et al.* 2007, Yang 2006a, 2006b). Filtration of sediments is another option. Glass fiber filters with a nominal pore size of 0.7 μm or 0.45 μm are often used to remove the suspended sediments or both suspended sediments and dissolved organic matter, but the filters can interfere with the detection of hydrophobic contaminants. Gomez-Gutierrez *et al.* (2007) found that adsorption to filters was positively correlated with the log K_{ow} and solubility values of the compounds, and that on average 58% of the one pyrethroid tested (a 50 ng/L solution of permethrin) was lost on the filter. This loss may be critical for determining compliance at environmental concentrations.

Alternately, the following equation can be used to translate total bifenthrin concentrations measured in water to the associated dissolved bifenthrin concentrations:

$$C_{dissolved} = \frac{C_{total}}{1 + ((K_{OC} \cdot [SS]) / foc) + (K_{DOC} \cdot [DOC])} \quad (1)$$

where: $C_{dissolved}$ = concentration of chemical in dissolved phase (μg/L);
C_{total} = total concentration of chemical in water (μg/L);
K_{OC} = organic carbon-water partition coefficient (L/kg);
[*SS*] = concentration of suspended solids in water (kg/L);
f_{oc} = fraction of organic carbon in suspended sediment in water;
[*DOC*] = concentration of dissolved organic carbon in water (kg/L);
K_{DOC} = organic carbon-water partition coefficient (L/kg) for DOC.

To determine compliance by this calculation, a site specific K_{OC} and suspended sediment data are required, including the concentration and the fraction of organic carbon. The sorption of bifenthrin to suspended solids and dissolved organic matter depend on the physical and chemical properties of the suspended solids resulting in a range of K_{OC} values (see section 3). This suggests that bioavailability may not be predicted based on a simple relationship and should not be estimated without site-specific data. Generating this site-specific data is fairly laborious, making SPME a more desirable choice.

While the literature suggests that the freely dissolved bifenthrin concentrations are the most accurate predictor of toxicity, the eight (of nine) available toxicity values used to derive the acute criterion are based on nominal values. These toxicity values are not measured whole-water concentrations or freely dissolved concentrations, by either of the methods described above. The problem is illustrated when examining the three toxicity values from Anderson *et al.* (2006), including those for: *Chironomus dilutus* (formerly *C. tentans*), *Procloeon sp.,* and *Hyalella azteca*, which are the lowest values in the data set. Some of the bifenthrin concentrations were measured in this study, but not enough for use in deriving the LC_{50} values. The recovery of bifenthrin averaged about 30% of the nominal at concentrations close to the toxicity value for *Hyalella*, making the LC_{50} value

of 9 ng/L perhaps a dissolved concentration of about 3 ng/L. Around the toxicity values for *Procloeon sp.* and *Chironomus dilutus,* recovery was about 60%. The authors of this study and others (Froelich *et al.* 1984, Wheelock *et al.* 2005) discuss how there is likely considerable loss to the sides of glass containers and the LC_{50} is probably much lower than they reported. Nominal toxicity values used in this report likely underestimate the sensitivity of organisms to bifenthrin.

Additionally, Xu *et al.* (2007) performed a 10-day spiked sediment bioassay with *Chironomus dilutus*. The reported LC_{50} values for C_{free} (the concentration freely dissolved in the porewater, determined with SPME) ranged from 0.048-0.053 μg/L, and LC_{50} values for total pore water concentrations ranged from 0.25-0.61 μg/L, more than an order of magnitude larger than the values based on C_{free}. Clearly the measured freely dissolved pore water concentration does not reflect the nominal water concentrations of the lab exposure in this case. The LC_{50} value based on nominal concentrations for *Chironomus dilutus* from Anderson *et al.* (2006) from a water only test was 2.6 μg/L, several orders of magnitude larger than the values calculated for the sediment exposure tests by Xu *et al.* (2007). This indicates that criteria determined with nominal values are unlikely to be protective if compliance is based on measured freely dissolved concentrations, because the criteria based on nominal values will not reflect the true sensitivity of organisms to freely dissolved bifenthrin.

At this time we recommend that criteria compliance be based on whole-water bifenthrin concentrations. Criteria based on nominal concentrations are likely to be underprotective and the role of dietary exposure has not been characterized; however, the use of whole-water concentrations is likely to be overprotective. The use of whole-water bifenthrin concentrations for compliance is currently the best way to ensure protection, compensating for the use of nominal concentrations and unknown effects of dietary exposure. This recommendation should be revised when more toxicity data based on measured concentrations are available.

12. Mixtures

Bifenthrin often occurs in the environment with other pyrethroid pesticides (Werner & Moran 2008). Since compounds in this class have a similar mode of action, either the toxic unit or the relative potency factor approach can be used to determine compliance in cases where pyrethroid mixtures are present in environmental samples as presented in section 3-5.2.1 of the methodology (TenBrook *et al.* 2009a).

Piperonyl butoxide (PBO) is commonly added to pyrethroid insecticide treatments because it is known to increase the toxic effects of pyrethroids (Weston *et al.* 2006). No interaction coefficients (K) have been derived with relevant species to describe synergism between bifenthrin and PBO. Consequently, it is not possible to quantify this non-additive toxicity and there is no accurate way to account for this interaction in compliance determination.

No studies on aquatic organisms were found in the literature that could provide a quantitative means to consider mixtures of bifenthrin with other classes of pesticides. However, several studies have been published that examine the interactive nature of bifenthrin with other pesticides and pesticide synergists in order to more effectively reduce a target pest or limit target insect resistance. The response of aquatic organisms, especially arthropods, may be comparable to the response of these targeted species (Werner & Moran 2008).

Several studies have used two similar methods to calculate the level of interaction between mixtures of bifenthrin. While their indexes do not provide a way to determine the toxicity of environmental mixtures, they provide information about the qualitative interaction. Bifenthrin toxicity to the diamondback moth (*Plutella xylostella*) was synergized by emamectin and spinosad, and were additive with those of chlorpyrifos and indoxacarb (Attique *et al.* 2006). Chlorpyrifos-methyl, another organophosphate pesticide, synergized effects of bifenthrin on the mosquito (*Anopheles gambiae,* Bonnet *et al.* 2004). Bifenthrin toxicity to the twospotted spider mite (*Tetranychus urticae)* was synergized by acephate, amitraz, chlordimeform, profenofos, s,s,s-tributyl phosphorotrithionate (DEF), and dimethoate (Bynum *et al.* 1990, Bynum *et al.* 1997). In the Banks grass mite (*Oligonychus pratensis)* amitraz and s,s,s-tributyl phosphorotrithionate (DEF) were synergistic (Bynum *et al.* 1997, Bynum & Archer 2002), while results with PBO varied from slightly synergistic to antagonistic (Bynum *et al.* 1997, Bynum & Archer 2002). It should also be noted that significant differences in response were observed between two closely related species tested in these studies (Bynum *et al.* 1997), which indicates that closely related aquatic organisms may also display a highly varied response to the same mixture of pesticides.

The silkworm, *Bombyx mori* (L.), a non-target organism, was exposed to leaves treated with a binary mixture of OP insecticides (dichlorvos and phoxim) and pyrethroid insecticides (permethrin, tetramethrin, bifenthrin, and ethofenprox), and experienced additive toxicity from the combination of pesticides (Zhang *et al.* 2008).

Although there are many examples of non-additive toxicity for bifenthrin and other chemicals, a multispecies interaction coefficient is not available for any chemical with bifenthrin, and therefore the concentrations of non-additive chemicals cannot be used for criteria compliance (section 3-5.2.2, TenBrook *et al.* 2009a).

13. Temperature, pH, and Other Water Quality Effects

Temperature has been found to be inversely proportional to the aquatic toxicity and bioavailability of pyrethroids (Miller & Salgado 1985, Werner & Moran 2008). In fact, the increase of toxicity of pyrethroids with decreasing temperature has been used to implicate pyrethroids as the source of toxicity in environmental samples (Phillips *et al.* 2004). The inverse relationship between temperature and pyrethroid toxicity is likely due to the increased sensitivity of an organism's sodium channels at low temperatures (Narahashi *et al.* 1998).

The toxicity of sediments contaminated with pyrethroids (often bifenthrin) was more than twice as toxic when tested at 18 ˚C compared to 23 ˚C (Weston *et al.* 2008). The enhanced toxic effects of pyrethroids at lower temperatures may not be as accurately represented by the results of typical laboratory toxicity tests, which tend to be run at warmer temperatures, 20-23 ˚C (USEPA 1996a, USEPA 1996b, USEPA 2000), than those of the habitats of coldwater fishes, about 15 ˚C or lower (Sullivan *et al.* 2000).

In studies that used topical exposures (more relevant to spray application exposure to target a pest), the difference in toxicity can increase by a factor of about 1.5 to a factor of 10, in the temperature range of about 10 to 27 ˚C (Kumaraguru & Beamish 1981; Punzo 1993; Schnitzerling 1985). A simple relationship of temperature and the binding of pyrethroids to a site of action may account for the increase of toxicity for permethrin to the cattle tick *Boophilus-microplus* (Schnitzerling 1985).

Unfortunately, there is limited data in this regard using aquatic exposures with aquatic species, making it infeasible to quantify the relationship between the toxicity of bifenthrin and temperature for water quality criteria at this time (section 3-5.3, TenBrook *et al.* 2009a). No studies on bifenthrin were found that examined the effects of pH or other water quality parameters on toxicity, thus, there is no way to incorporate any of these parameters into criteria compliance.

14. Sensitive Species

It is important to evaluate the derived criteria to ensure that they will be protective of particularly sensitive species that may not be represented in the highly rated (RR) data set (sections 3-6.0 and 3-6.1, TenBrook *et al.* 2009a). The calculated acute and chronic bifenthrin criteria (4 and 0.3 ng/L, respectively) are below the lowest acute and chronic freshwater toxicity values in the data set. The lowest reported acute toxicity value in the highly rated data set (rated RR, data used directly in criteria calculation) is 2.7 ng/L for *Hyalella azteca* (Table 2). Studies in the supplemental data set (rated RL, LR, or LL, data not used directly in criteria calculation) contain the toxicity value of 3.97 ng/L *Mysidopsis bahia* (Table 6), which is slightly below the acute criterion. The values for mysid are in the supplemental category because they are saltwater values, which may or may not be similar to toxicity values in freshwater.

The lowest reported bifenthrin chronic toxicity value in the highly rated (RR) data set is a maximum acceptable toxicant concentration (MATC) of 1.9 ng/L for *Daphnia magna* (Table 3). In the supplemental data set, there is a chronic toxicity value of 1.25 ng/L for *Mysidopsis bahia* (Table 6). Both the acute and chronic criteria, as calculated, appear to be protective of freshwater organisms based on the available data.

15. Ecosystem and Other Studies

Four studies describing bifenthrin effects on microcosm, mesocosm and model ecosystems were rated acceptable (R or L reliability rating using Table 3.9, TenBrook *et al.* 2009a). Several bifenthrin mesocosm tests were carried out with bifenthrin in the

sediments, but bifenthrin was also measured in the water column. These studies simulate real world conditions, in which most of the bifenthrin would likely be sediment bound. In Hoagland *et al.* (1993), the effects of sediment-associated bifenthrin alone and in combination with atrazine were examined using tanks containing natural plankton assemblages and bluegill. Bifenthrin was found to reduce the number of cladocerans (*Bosmina*), cyclopoid copepodids and copepods after 7 days at a concentration as low as 20 to 60 ng/L, while bluegill suffered 33% mortality at 3150 ng/L. Also, Drenner *et al*. (1993) looked at the effect of sediment-associated bifenthrin on gizzard shad and plankton in outdoor tank mesocosms. Eight day LC_{50} values for gizzard shad ranged from 207 - 521 ng/L (based on water concentrations 1 hour after sediment spiked with bifenthrin was added). In the same mesocosms, there was a significant decrease in copepod density and an increase in rotifer density. Surprenant (1988) conducted experiments with soil that was spiked with 0.1 to 1 mg/kg bifenthrin in clean dilution water. Organisms were exposed to water only via circulation though different chambers for 21 days. *Daphnia magna* survival was significantly affected at 0.59 µg/L of bifenthrin. Survival of *Asellus sp*. was affected at bifenthrin concentrations of 0.30 µg/L and above. No toxic effects were seen in *Pimephales promelas* at 1.86 µg/L in water, and no toxic effects were seen in *Corbicula sp*. at 2.58 µg/L and below. In these studies the toxic effects reported are all from concentrations above the proposed acute and chronic bifenthrin criteria of 4 ng/L and 0.3 ng/L, respectively. The criteria are judged to be protective based on these ecosystem studies, but will not be adjusted upward because single species data have indicated the derived criteria to be protective (section 3-6.2, TenBrook *et al* 2009a).

To assess possible effects of bifenthrin field applications, Sherman (1989) documented extensive surveys of the aquatic organisms in two experimental ponds from 1986-1988, as well as *in situ* bioassays using *Daphnia magna* and *Pimephales promelas* exposures to spray drift and runoff. In the summer of 1986, ten weekly applications of a commercial formulation of bifenthrin, Capture 2.0, were sprayed on to agricultural fields at a rate of twice the then current label maximum (0.1 lbs/acre). These fields drained into nearby Hagan's Pond, which was a little over 3 acres in size. Observed toxic effects were compared to data from a reference pond 19 km to the north. The post application follow-up studies continued through August of 1987 and again in the summer of 1988, monitoring for recovery.

Of the zooplankton, calanoid copeopods were clearly affected, while cladocerans showed some bifenthrin related effects. The survival and reproduction of ramshorn snail were negatively affected. Macroinvertebrates reduced in both density and number, but showed recovery. The bioassays with *Daphnia magn*a and *Pimephales promelas* showed significant toxic effects and recovery. Phytoplankton, caged shrimp and crayfish exposed showed no clear effects. Mussels were unaffected and fish suffered no acute affects. There was a gizzard shad die off in the winter of 1987-88, but this seems to have not been bifenthrin related, as it did not correlate well to high concentrations of bifenthrin. Unfortunately the concentrations of bifenthrin cannot be directly tied to the observed effects. Average pond concentrations fluctuated from slightly above 1 ng/L to almost 10 ng/L from the summer of application until the next summer. The highest concentrations

occurred in the summer of treatment, but overall there was not a clear temporal pattern as high concentrations were also observed in February and March of 1987, even though spraying ended in August of 1986 (see also Figure 1 in Palmieri 1988). The report also notes that herbicides and fertilizers were also applied during the study period. Since the concentrations that caused toxicity are not clear, this study cannot be used to judge if the acute criterion of 4 ng/L and a chronic criterion of 0.3 ng/L will be protective.

Several recent studies on the toxicity of pyrethroid mixtures, inclusive of bifenthrin, have been performed by Donald Weston and colleagues at the University of California, Berkeley. These studies do not rate as high quality field or mesocosm studies by the methodology (section 3-6.2 and Table 3.9, TenBrook *et al.* 2009a) because they are not controlled exposures, but use environmental samples that could contain many chemicals. However, these studies are summarized here because they provide evidence that bifenthrin is bioavailable and present at concentrations toxic to aquatic life in several areas of the California Central Valley. They also utilize toxicity identification evaluations (TIEs) that use several lines of evidence to identify the agents causing toxicity in samples, and the methodology does not have a rating scheme or parameter for TIE data.

Weston *et al.* (2005) collected sediments from creeks near residential areas of Roseville, CA. Almost half of the sampled sites (9 of 21), caused > 90 % mortality to the *Hyalella azteca*. Bifenthrin, a common ingredient in lawn-care products, was implicated as the primary cause of toxicity, followed by cyfluthrin and cypermethrin. Another study, performed in 2006, confirmed that residential high pyrethroid use, particularly of bifenthrin, was causing significant toxicity in urban creeks. This study found that most samples colleted from creeks in a variety of Sacramento area locations were lethal to *Hyalella azteca* in lab tests, while the highest mortality occurred in samples from housing subdivisions (Amweg *et al.* 2006). Bifenthrin has also been implicated in toxicity in creeks that catch agriculture runoff. Sediment samples collected from six sites along a six kilometer stretch of Del Puerto Creek all caused > 70 % mortality in toxicity tests with *Hyalella azteca.* Bifenthrin was identified as the primary contributor to toxicity in nearly all sites at which toxicity was observed (Weston *et al.* 2008). These results demonstrate toxicity at environmental concentrations, but unfortunately none of these studies included associated water concentrations of bifenthrin to compare with the derived acute and chronic bifenthrin criteria in this report.

16. Threatened and Endangered Species

In order to investigate if the derived criteria will be protective of threatened and endangered species (section 3-6.3, TenBrook *et al.* 2009a) the current lists of state and federally listed threatened and endangered animal species in California were obtained from the California Department of Fish and Game web site (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/TEAnimals.pdf; CDFG 2008). Only one of the listed animals is represented in the acute or chronic toxicity data set, steelhead trout (*Oncorhynchus mykiss)*, with an LC_{50} of 0.15 μg/L. No threatened or endangered species are listed in the supplemental data set (Table 6).

Some of the listed species are represented in the acute toxicity data set by members of the same family or genus. *Oncorhynchus mykiss* and *Pimephales promelas* can serve as surrgates in estimates for other species in the same family using the USEPA interspecies correlation estimation website (WEB-ICE v. 2.0; Raimondo *et al.* 2007). Unfortunately, the bifenthrin toxicity values were out of range of the values used to develop the model for most of the available species. Only a value of 0.252 μg/L could be estimated for Coho salmon *(Oncorhynchus kisutch).* Other estimations could be made more generally for the families of Salmonidae and Cyprinidae. These estimates are 0.237 μg/L for Salmonidae to 0.307 μg/L for Cyprinidae and are shown with the listed endangered species of that family in Table 8.

No single species plant studies were found in the literature for use in criteria derivation, so no estimation could be made for plants on the state or federal endangered, threatened or rare species lists. In a pond study, phytoplankton were unaffected by bifenthrin (Sherman 1989). However, bifenthrin seemed to be beneficial in some instances and harmful in others, as reported in a mesocosm study that monitored primary productivity, green algae, chlorophyll, and other endpoints for photosynthetic organisms (Hoagland *et al.* 1993). Based on the mode of action, plants should be relatively insensitive to bifenthrin and the calculated bifenthrin criteria should be protective of aquatic plants.

The lowest toxicity value, from either experimental or estimated datasets, for a threatened or endangered species is the experimental LC_{50} value of 0.15 μg/L for *Oncorhynchus mykiss* that was used in bifenthrin criteria derivation calculation. Therefore, based on the available data and the estimated values for animals, there is no evidence that the calculated acute and chronic bifenthrin criteria will be underprotective of threatened or endangered species. However, it is important to note that this assessment lacks data for crustaceans and insects, which would be the most sensitive species in the acute criterion data set for bifenthrin. No data were found for effects of bifenthrin on federally endangered crustaceans or insects, or acceptable surrogates (i.e., in the same family).

17. Bioaccumulation

Bifenthrin has a mean log K_{ow} of 6.0 and a molecular weight of 422.87 (section 3), which indicates its bioaccumulative potential (section 3-7.1, TenBrook *et al.* 2009a). No biomagnification factor (BMF) values were found in the literature for bifenthrin. Bioaccumulation of bifenthrin has been measured in several studies (Table 1), which are briefly summarized here. The bioconcentration Factor (BCF) in fish varied from 45 to 28,000 depending on the age of the fish and if the analysis was based on residues in the whole body or just the portion that a human might consume (fillet). A 1986 study that examined the elimination of bifenthrin from the bluegill found that this pyrethroid is very slowly eliminated from tissues. After 42 days of depuration, fish tissue concentrations of bifenthrin were reduced by about half (Surprenant 1986). A recent study with *Daphnia magna* found that the Bioaccumulation Factor (BAF) varies greatly with differing concentrations of suspended sediments. BAFs in *Daphnia magna* ranged from 1000 to 4,600. As the concentration of suspended sediments was increased (0-200 mg/L), the associated BAF values decreased to 1,000 to 2,600 times (Yang *et al.* 2006a).

To check that these criteria are protective of terrestrial wildlife that may consume aquatic organisms, a bioaccumulation factor (BAF) will be used to estimate the water concentration that would roughly equate to a reported toxicity value for consumption of fish by terrestrial wildlife. These calculations are further explained in section 3-7.1 of the methodology (TenBrook *et al.* 2009a). The BAF of a given chemical is the product of the bioconcentration factor (BCF) and a biomagnification factor (BMF), such that BAF=BCF*BMF. For a conservative estimate, the BCF value of 28,000 L/kg for whole fish will be used (McAllister 1988, Table 1). A default BMF value of 10 is used, based on the log K_{ow} of bifenthrin (Table 3.17, TenBrook *et al.* 2009a). An oral predator NOEC value of 75 mg/kg feed is used (Roberts *et al.* 1986), although toxicity was not observed at any of the three doses tested (25, 50, 75 mg/kg), making this likely an underestimated NOEC value. This dose will be used because there were effects seen at the lowest dose (312 mg/kg feed) in a mallard duckling study by Fletcher (1983a).

$$NOEC_{water} = \frac{NOEC_{oral\_predator}}{BCF_{food\_item} * BMF_{food\_item}}$$

Mallard: $$NOEC_{water} = \frac{75\ ^{mg}/_{kg}}{28{,}000\ ^{L}/_{kg} * 10} = 0.000267\ ^{mg}/_{L} = 0.267\ ^{\mu g}/_{L} = 267\ ^{ng}/_{L}$$

To check that these criteria are protective of humans that may consume aquatic organisms, a BAF will be used to estimate the water concentration that would roughly equate to a limit for human food consumption. An appropriate BAF was not available in the data set. The BCF value of 2140 L/kg for fish fillet (Surprenant 1986, Table 1) and a human food tolerance level are used. There are no tolerance or FDA action levels for fish tissue (USFDA 2000), but there are food tolerances for meat of cattle, goat, hogs, horses, and sheep at 0.5 ppm (USEPA 2006c). This value can be used to roughly estimate if

bioconcentration could cause bifenthrin concentrations in fish tissues to be of concern to human heath.

Human: $$NOEC_{water} = \frac{0.5\ ^{mg}/_{kg}}{2{,}140\ ^{L}/_{kg} * 10} = 0.0000234\ ^{mg}/_{L} = 0.0234\ ^{\mu g}/_{L} = 23\ ^{ng}/_{L}$$

In this example, the derived chronic criterion of 0.3 ng/L is more than an order of magnitude below the estimated water concentrations of concern for wildlife and humans (267 ng/L and 23 ng/L). Therefore, adhering to the derived bifenthrin criteria should not conflict with other efforts to protect wildlife or human health from bifenthrin exposure.

18. Harmonization with Air and Sediment Criteria

This section addresses how the maximum allowable concentration of bifenthrin might impact life in other environmental compartments through partitioning (section 3-7.2, TenBrook *et al.* 2009a). However, there are no federal or state sediment or air quality standards for bifenthrin (California Air Resources Board 2005, USEPA 2006a, USEPA 2006b, California Department of Water Resources 1995) to enable this kind of extrapolation. For biota, the limited data on bioconcentration or biomagnification of bifenthrin was addressed in the bioaccumulation section (section 17).

19. Assumptions, Limitations and Uncertainties

The assumptions, limitations and uncertainties involved in criteria derivation should be available to inform environmental managers of the accuracy and confidence in the derived criteria (section 3-8.0, TenBrook *et al.* 2009a). Chapter 2 of the methodology discusses these points for each section as different procedures were chosen, such as the list of assumptions associated with using a species sensitivity distribution (SSD), included in section 2-3.1.5.1, and reviews the assumptions in section 2-7.0 (TenBrook *et al.* 2009a). The different calculations of distributional estimates included in section 9 of this report may be used to consider the uncertainty in the resulting acute criterion.

For bifenthrin, the major limitation was in the chronic toxicity data set. Three of five taxa requirements were not met (the salmonid, benthic crustacean and insect), which precluded the use of a SSD; therefore, an acute to chronic ratio (ACR) was used to derive the chronic criterion. Since no acceptable ACRs were available for bifenthrin in the literature, the default value of 12.4 was used (as specified in section 3-4.2.3, TenBrook *et al.* 2009a). Particularly of concern for the chronic toxicity data set was the lack of data on *Hyalella azteca,* which was the most sensitive species in the acute toxicity data set.

Another concern that could not be accounted for quantitatively with the acute and chronic criteria is the increase in toxicity from lower temperatures. Most of the toxicity data were from tests performed at standard temperature, usually around 20 ˚C. However, many streams in the California Central Valley often have lower water temperatures. If colder water bodies are impacted by concentrations of bifenthrin, it may be appropriate to apply an additional safety factor to the bifenthrin criteria for those areas, to ensure

adequate protection. A rough factor of two could be estimated from a study by Weston *et al.* (2008), however, a study relating temperature to toxicity of bifenthrin in *Hyalella azteca* would be ideal to derive such an adjustment factor.

20. Comparison to National Standard Methods

This section is provided as a comparison between the new methodology for criteria calculation (TenBrook *et al.* 2009a) and the current USEPA (1985) national standard. The following example bifenthrin criteria were generated using the USEPA 1985 methodology with the data set generated in this bifenthrin criteria report.

The USEPA acute methods have 3 additional taxa requirement beyond the 5 required by the methodology used in this criteria report (section 3-3.1, TenBrook *et al.* 2009a). They are:

1. A third family in the phylum Chordata (e.g., fish, amphibian);
2. A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca);
3. A family in any order of insect or any phylum not already represented.

Two out of the three of these additional requirements are met as follows:

1. The other fish /amphibian requirement is met with data from fathead minnow.
2. This requirements not met because all data are from organisms in the phylum Arthropoda or Chordata.
3. This requirement is met because *Chironomus dilutus* (family: Diptera) is from a different family than *Procloeon sp.* (family Ephemeroptera).

Strictly speaking, the USEPA methodology cannot be used to calculate an acute criterion for bifenthrin. However, since the California Department of Fish and Game have used data sets that met only seven of eight requirements in the USEPA methodology, this will be done here.

Using the log-triangular calculation (following the USEPA 1985 guidelines) and the bifenthrin data set from Table 2 containing eight species values, the following criterion was calculated (Note: USEPA methodology uses *genus* mean acute values, while *species* mean acute values are used in this methodology and are reported in Table 2. Since there is only one species from each genus in Table 2, this final data set would be the same in both schemes.):

Example Acute value (5^{th} percentile value) = 0.004725

Example Acute Criterion = acute value ÷ 2
= 0.004725 µg/L ÷ 2 = 0.002363 µg/L
= 2 ng/L

For the chronic criterion, the bifenthrin data set only has data from 2 species, which are not enough for use in a species sensitivity distribution by either method. The USEPA 1985 methodology contains a similar acute to chronic ratio (ACR) procedure as in the methodology used in this criteria report, to be used when three acceptable ACRs are available. For cases in which three acceptable ACRs are not available, the USEPA methodology does not have a default ACR or alternative procedure. Since no acceptable ACR could be calculated with the bifenthrin data set, no chronic criterion can be calculated using the USEPA 1985 methodology.

21. Final Bifenthrin Criteria Statement

The final criteria statement is:

Aquatic life in the Sacramento River and San Joaquin River basins should not be affected unacceptably if the four-day average concentration of bifenthrin does not exceed 0.3 ng/L more than once every three years, on the average, and if the one-hour average concentration of bifenthrin does not exceed 4 ng/L more than once every three years on the average.

To date, there are no USEPA water quality criteria or aquatic life benchmarks for bifenthrin. The California Department of Fish and Game (CDFG) composed a risk assessment report for synthetic pyrethroids (Siepmann & Holm 2000). CDFG concluded that there was insufficient data to calculate criteria for bifenthrin using the USEPA (1985) methods. This report is concluded by reporting the lowest acute and chronic toxicity values found. The lowest genus mean acute value (GMAV) for bifenthrin was 3.97 ng/L for *Mysidopsis bahia* and the lowest Maximum Acceptable Toxicant Concentration (MATC) was 60 ng/L for *Pimephales promelas*. The chronic criterion in this report is below the lowest chronic toxicity value from the CDFG report. The lowest acute toxicity value from the CDFG report is below the criteria derived here, but it is for a saltwater species which may be more sensitive than freshwater species. Solomon *et al.* (2001) performed a probabilistic risk assessment with pyrethroids. Saltwater and freshwater toxicity data were combined so the lowest toxicity value in the data set was 3.8 ng/L (for mysid, a saltwater species). The 5^{th} percentile value for bifenthrin, based on a log-normal distribution, was also 3.8 ng/L, although much of the author's discussion centered on the 10^{th} percentile as the protective limit, which was 15 ng/L for bifenthrin. For compounds that had larger toxicity data sets, separate analyses were performed for freshwater and saltwater data. Differences were found especially for invertebrates, which suggested that the risk to freshwater and saltwater organisms should be assessed separately.

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Data Tables

Table 2. Final acute toxicity data set for bifenthrin. All studies were rated Relevant and Reliable (RR) and were conducted at standard temperature. Values in bold are species mean acute values. S: static, SR: static renewal, FT: flow-through.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC_{50}/EC_{50} (µg/L)	Reference
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Nom	97.8%	96 h	24.0-24.7	Mortality	<24 h	**0.078**	Guy 2000a
Chironomus dilutus (formerly *C. tentans*)	Midge	Chironomidae	S	Meas	100.0%	96 h	23 ± 1	Mortality	3rd instar	**2.615**	Anderson et al. 2006
Daphnia magna	Cladoceran	Daphniidae	FT	Nom	88.4%	48 h	20-21	Mortality	<24 h	**1.6**	Surprenant 1983 MRID 132537
Hyalella azteca	Amphipod	Hyalellidae	S	Meas	100.0%	96 h	23 ± 1	Mortality	7-14 d	0.0093	Anderson et al. 2006
Hyalella azteca	Amphipod	Hyalellidae	SR	Meas	98%	96 h	23 ± 1	Mortality	7-14 d	0.0027	Weston & Jackson 2009
Hyalella azteca	Amphipod	Hyalellidae	SR	Meas	98%	96 h	23 ± 1	Mortality	7-14 d	0.0073	Weston & Jackson 2009
Hyalella azteca	Amphipod	Hyalellidae	SR	Meas	98%	96 h	23 ± 1	Mortality	7-14 d	0.0080	Weston & Jackson 2009
Hyalella azteca	Amphipod	Hyalellidae	SR	Meas	98%	96 h	23 ± 1	Mortality	7-14 d	0.0082	Weston & Jackson 2009
Hyalella azteca										**0.0065**	GEOMEAN
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	96 h	21-22	Mortality	2.5 g, 8 mm	**0.35**	Hoberg 1983a MRID 00132536
Onchorynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	96 h	11-12	Mortality	1.0 g, 46 mm	**0.15**	Hoberg 1983b MRID 00132539
Pimephales promelas	Fathead minnow	Cyprinidae	S	Meas	96.2%	96 h	25 ± 1	Mortality	40 d, 0.059g	0.21	McAllister 1988 MRID 40791301
Pimphales promelas	Fathead minnow	Cyprinidae	SR	Nom	97.8%	96 h	24.0-24.5	Mortality	8 d, 0.0039-0.0052g	0.78	Guy 2000b

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC_{50}/EC_{50} (µg/L)	Reference
Pimephales promelas										**0.405**	GEOMEAN
Procloeon sp	Mayfly	Baetidae	S	Meas	100.0%	48 h	23 ± 1	Mortality	0.5-1.0 cm	**0.0843**	Anderson et al. 2006

Table 3. Acceptable acute toxicity data for bifenthrin excluded in data reduction process. All studies were rated relevant and reliable (RR). S: static, FT: flow-through.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC_{50}/ EC_{50} (µg/L)	Reference	Reason for exclusion
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	97.0%	48 h	25	Mortality	<24 h	0.142	Wheelock et al. 2004	1
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	48 h	21-22	Mortality	2.5 g, 58 mm	0.65	Hoberg 1983a MRID 132536	1
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	72 h	21-22	Mortality	2.5 g, 58 mm	0.44	Hoberg 1983a MRID 132536	1
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	144 h	21-22	Mortality	2.5 g, 58 mm	0.3	Hoberg 1983a MRID 132536	1
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	24 h	11-12	Mortality	1.0 g, 46 mm	6.2	Hoberg 1983b MRID 132539	1
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	48 h	11-12	Mortality	1.0 g, 46 mm	0.34	Hoberg 1983b MRID 132539	1
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	72 h	11-12	Mortality	1.0 g, 46 mm	0.2	Hoberg 1983b MRID 132539	1
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	120 h	11-12	Mortality	1.0 g, 46 mm	0.1	Hoberg 1983b MRID 132539	1

Reasons for exclusion
1. A more sensitive or more appropriate test duration was available from the same test.

Table 4. Final chronic toxicity data set for bifenthrin. All studies were rated relevant and reliable (RR). FT: flow-through.

Species	Common identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference
Daphnia magna	Cladoceran	FT	Meas	97.0%	21 d	19-22	Reproduction	< 24 h	0.0013	0.0029	0.0019	Burgess 1989 MRID 41156501
Pimephales promelas	Fathead minnow	FT	Meas	96.2%	92 d	25	Mortality	< 48 h	0.040	0.090	0.060	McAllister 1988 MRID 40791301

Table 5. Acceptable chronic toxicity data for bifenthrin excluded in data reduction process. All studies were rated relevant and reliable (RR). FT: flow-through.

Species	Common identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference	Reason for exclusion
Daphnia magna	Cladoceran	FT	Meas	97.0%	21 d	19-22	Time to 1st brood	< 24 h	0.0029	0.0076	0.0047	Burgess 1989	1
Daphnia magna	Cladoceran	FT	Meas	97.0%	21 d	19-22	Length	< 24 h	0.0029	0.0076	0.0047	Burgess 1989	1

Reasons for exclusion
1. More sensitive endpoint available from same test

Table 6. Supplemental studies excluded from bifenthrin criteria derivation (rated less relevant and/or less reliable: RL, LR, or LL). S: static, FT: flow-through.

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC_{50}/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating/ Reason
Ceriodaphnia dubia	Cladoceran	S	Meas	25.4%	48 h	18 + 1	Survival	< 24 h	0.07	-----	Mokry & Hoagland 1990	LR 1
Ceriodaphnia dubia	Cladoceran	S	Nom	96%	96 h	20	Mortality	< 24 h	0.079	-----	Liu et al. 2005	RL 2, 5
Ceriodaphnia dubia	Cladoceran	S	Nom	98%	96 h	21	Mortality	< 24 h	0.05	-----	Yang et al. 2006b	RL 5
Cheumatopsyche spp. & *Hydropsyche* spp.	Caddisfly	S	Nom	94%	24 h	20	Mortality	Larvae	7.2	-----	Siegfried 1993	RL 5
Crassostrea virginica	Eastern oyster	FT	Meas	88%	96 h	24	Reduced shell growth	31-50 mm height	> 2.15	-----	Ward 1986a MRID 470271040	LR 3, 4
Crassostrea virginica	Eastern oyster	FT	Meas	88%	96 h	26	Reduced shell growth	36-50 mm height	> 99.7	-----	Ward 1986b MRID 40266501	LR 3, 4
Cyprinodon variegatus	Sheepshead minnow	FT	Meas	88%	96 h	19.9-22.3	Survival	9 wk	17.8	-----	Barrows 1986a MRID 470271038	LR 3
Daphnia magna	Cladoceran	FT	Meas	10.4%	48 h	19-21	Survival	≤ 24 h	0.11	-----	Hoberg et al. 1985 MRID 40275401	LR 1
Daphnia magna	Cladoceran	FT	Meas	10.4%	21 d	19-21	Survival	≤ 24 h	-----	0.01929	Hoberg et al. 1985 MRID 40275401	LR 1
Daphnia magna	Cladoceran	FT	Meas	10.4%	21 d	19-21	Reproduction	≤ 24 h	-----	0.0014	Hoberg et al. 1985 MRID 40275401	LR 1
Enellagma spp. & *Ishnura* spp.	Damselfly	S	Nom	94%	24 h	20	Mortality	Nymph	1.1	-----	Siegfried 1993	RL 5
Heptageniidae spp.	Mayfly	S	Nom	94%	24 h	20	Mortality	Nymph	2.3	-----	Siegfried 1993	RL 2, 5
Hydrophilus spp.	Diving beetle	S	Nom	94%	24 h	20	Mortality	Adult	5.4	-----	Siegfried 1993	RL 5

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC_{50}/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating/ Reason
Mysidopsis bahia	Mysid shrimp	FT	Meas	88%	96 h	21.5-21.6	Mortality	< 24 h	0.00397	-----	Barrows 1986b MRID 470271039	LR 3
Mysidopsis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.5-25.7	Survival, F1	< 24 h	-----	0.00125	Boeri & Ward 1991 MRID 42338801	LR 3
Mysidopsis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.5-25.7	Reproduction, young per female	< 24 h	-----	0.00343	Boeri & Ward 1991 MRID 42338801	LR 3
Mysidopsis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.5-25.7	Growth, F1 length	< 24 h	-----	0.00125	Boeri & Ward 1991 MRID 42338801	LR 3
Mysidopsis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	Survival F1,	< 24 h	-----	0.0025	Ward & Boeri 1991 MRID 41640501	LR 2, 3
Mysidopsis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	Young per female,	< 24 h	-----	0.0025	Ward & Boeri 1991 MRID 41640501	LR 2, 3
Mysidopsis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	F1 length,	< 24 h	-----	0.0025	Ward & Boeri 1991 MRID 41640501	LR 1, 3
Mysidopsis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	Sublethal effects	< 24 h	-----	0.0025	Ward & Boeri 1991 MRID 41640501	LR 2, 3
Simulium vittatum	Blackfly	S	Nom	94%	24 h	20	Mortality	Larvae	1.3	-----	Siegfried 1993	RL 5

Reasons for Rating

1. Low chemical grade
2. Control response not reported or not acceptable
3. Not freshwater
4. No toxicity value calculated
5. Low reliability score

Table 7. Acceptable multispecies field, semi-field, laboratory, microcosm, mesocosm studies; R= reliable; L= less reliable.

Reference	Habitat	Rating
Drenner *et al.* (1993)	Outdoor tank mesocosm	R
Hoagland *et al.* (1993)	Outdoor tank mesocosm	R
Sherman (1989)	Outdoor ponds	R
Surprenant (1988)	Indoor laboratory microcosm	R

Table 8. Laboratory bifenthrin LC_{50} values for threatened or endangered species and predicted values, using WEB-ICE (Raimondo *et al.* 2007).

Species	Common Name	Family	LC_{50} (µg/L)	Surrogate
Lab determined values for endangered species				
Oncorhynchus mykiss	Steelhead	Salmonidae	0.15	None - experimental value
Predicted based on species specific model				
Oncorhynchus kisutch	Coho salmon	Salmonidae	0.252	*Oncorhynchus mykiss*
Predicted with the family based model for Salmonidae				
Oncorhynchus clarki	Coho salmon	Salmonidae	0.237	*Oncorhynchus mykiss*
Oncorhynchus mykiss	Steelhead	Salmonidae	0.237	*Oncorhynchus mykiss*
Oncorhynchus tshawytscha	Chinook salmon	Salmonidae	0.237	*Oncorhynchus mykiss*
Predicted with the family based model for Cyprinidae				
Gila elegans	Bonytail chub	Cyprinidae	0.307	*Pimephales promelas*
Ptychocheilus lucius	Colorado squawfish	Cyprinidae	0.307	*Pimephales promelas*

Appendix A

Data summary sheets for data rated relevant and reliable

Abbreviations used in this appendix:
NR = Not Reported
RR = Relevant, Reliable study

Unused lines deleted from tables

Summary sheets are in alphabetical order according to species

Toxicity Data Summary

Ceriodaphnia dubia

Study: Guy D. 2000a. Aquatic Toxicology laboratory Report P-2161-2. Bifenthrin with cladoceran *Ceriodaphnia dubia* in an acute definitive test. California Department of Fish and Game, Aquatic Toxicology Lab, Elk Grove, CA.

Relevance
Score: 100
Rating:R

Reliability
Score: 86.5
Rating: R

Reference	**Guy 2000a**	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	ASTM /EPA	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Family in North America?	Yes	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	In house culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	100% survival in solvent and dilution water controls	
Temperature	24.0 -24.7 ^{o}C	
Test type	Static w/ 48 h renewal	
Photoperiod/light intensity	16:8 light:dark	
Dilution water	NR	
pH	8.04-8.38	
Hardness	138-168 mg/L	
Alkalinity	152-184 mg/L	
Conductivity	328-447 µs/cm	
Dissolved Oxygen	7.74-8.36 mg/L	

Reference	**Guy 2000a**	***C. dubia***
Parameter	**Value**	**Comment**
Feeding	No	
Purity of test substance	97.8 %	
Concentrations measured?	No - estimated	
Measured is what % of nominal?	85% estimated from spikes	
Chemical method documented?	No	
Concentration of carrier (if any) in test solutions	0.0016 mL/L (acetone)	
Nominal and estimated (Est) concentrations (divided by a factor derived from recovery of spiked water samples on day 0 and day 2		
Concentration 1 Nom/Est (µg/L)	0.05/0.036	4 reps and 5 neonates per rep
Concentration 2 Nom/Est (µg/L)	0.1/0.036	4 reps and 5 neonates per rep
Concentration 3 Nom/Est (µg/L)	0.2/0.091	4 reps and 5 neonates per rep
Concentration 4 Nom/Est (µg/L)	0.4/0.153	4 reps and 5 neonates per rep
Concentration 5 Nom/Est (µg/L)	0.8/0.392	4 reps and 5 neonates per rep
Concentration 6 Nom/Est (µg/L)	1.6/0.861	4 reps and 5 neonates per rep
Controls	Water only and a solvent (acetone) control	4 reps and 5 neonates per rep
LC_{50} (95% Confidence interval)	0.078 (0.056-0.13) µg/L	Linear interpolation

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Dilution water source (3), Hypothesis tests (8)

Acceptability: Meas. Concentrations 20% Nom (4), Dilution water source acceptable (2), Hypothesis tests (3)

Toxicity Data Summary

Ceriodaphnia dubia

Study: Wheelock CE, Miller JL, Miller MJ, Gee SJ, Shan G, Hammock BD. 2004. Development of toxicity identification evaluation procedures for pyrethroid detection using esterase activity. Environmental Toxicology and Chemistry 23(11): 2699-2708.

Relevance
Score: 100
Rating: R

Reliability
Score: 77.5
Rating: R

Reference	**Wheelock *et al.* 2004**	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	EPA	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Family in North America?	Yes	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	AQUA-Science, Davis, CA	
Have organisms been exposed to contaminants?	Probably not	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	> 90%	
Temperature	25 $\pm$ 1 ºC	
Test type	Static	
Photoperiod/light intensity	16:8, light:dark	
Dilution water	EPA moderately hard	
pH	7.4-7.8	
Hardness	80-100 mg/L	
Alkalinity	60-70 mg/L	
Conductivity	Measured but NR	
Dissolved Oxygen	Measured but NR	
Feeding	None during test	
Purity of test substance	> 97%	

Reference	**Wheelock *et al.* 2004**	***C. dubia***
Parameter	**Value**	**Comment**
Concentrations measured?	No	
Measured is what % of nominal?	NR	
Chemical method documented?	NR	
Concentration of carrier (if any) in test solutions	< 1 %	
Concentration 1 Nom/Meas (μg/L)	5-7 concentrations	2-4 reps w/ 5 neonates each
Control	Water and methanol control	2-4 reps w/ 5 neonates each
LC_{50}	48 h: 0.142 $\pm$ 0.122 μg/L	ToxCal software, but no stat method reported

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Dissolved Oxygen (4), Conductivity (2), Statistical methods identified (5), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Concentrations do not exceed 2x water solubility (4), Carrier solvent $\leq$ 0.5 mL/L (4), Appropriate spacing between concentrations (2), Appropriate statistical method (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus dilutus (formerly *Chironomus tentans*)

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (CA, USA): Relative effects of pesticides and suspended particles. Environmental Pollution 141:402-408.

Relevance
Score: 90 (No standard method)
Rating: R

Reliability
Score: 79
Rating: R

Reference	**Anderson *et al.* 2006**	***C. dilutus***
Parameter	**Value**	**Comment**
Test method cited	NR	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*dilutus*	
Family in North America?	Yes	
Age/size at start of test/growth phase	3rd instar	
Source of organisms	Chesapeake Culture, Hayes, VA.	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	No	
Test duration	96 hr	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	90% survival*	
Temperature	23 ± 1 °C*	
Test type	Static	
Photoperiod/light intensity	16 light:8 dark*	
Dilution water	Well Water	
pH	NR	
Hardness	91.6 mg/L*	
Alkalinity	122.4 mg/L as $CaCO_3$*	
Conductivity	NR	

Reference	**Anderson *et al.* 2006**	***C. dilutus***
Parameter	**Value**	**Comment**
Dissolved Oxygen	NR	
Feeding	Not fed	
Purity of test substance	100%	
Concentrations measured?	Yes	
Measured is what % of nominal?	36-65%	Meas. 2 reps of only some conc's
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Used 100 mg/L methanol stock	
Concentration 1 Nom/Meas (µg/L)	0.560/ 200, 364	10 reps, 1 per rep
Concentration 2 Nom/Meas (µg/L)	1.8/ 0.964, 1.110	10 reps, 1 per rep
Concentration 3 Nom/Meas (µg/L)	5/ NR	10 reps, 1 per rep
Concentration 4 Nom/Meas (µg/L)	10/ NR	10 reps, 1 per rep
Concentration 5 Nom/Meas (µg/L)	20/ NR	10 reps, 1 per rep
Control	0/ NR	10 reps, 1 per rep
LC_{50}	2.615 µg/L	Method: Spearman-Karber

Other notes:

*Control survival, temp. variation photoperiod, and water chemistry obtained by personal communication with the testing laboratory.

Emailing author revealed typo in the article. The LC_{50} of 26 µg/L in the paper SHOULD READ 2.6 µg/L.

Reliability points taken off for:
Documentation: Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)
Acceptability: Standard method (5), Meas. Concentrations 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated (1), Dissolved oxygen (6), Conductivity (1), pH (2), Random design (2), Hypothesis tests (3)

Toxicity Data Summary

Daphnia magna

Study: Surprenant DC. 1983. Acute toxicity of FMC 54800 technical to *Daphnia magna*. Bionomics Study. FMC Study No: A83 / 986. MRID 00132537.

Relevance
Score: 100
Rating: R

Reliability
Score: 89
Rating: R

Reference	**Surprenant 1983**	***D. magna***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*magna*	
Native to	Northeastern United States	
Age/size at start of test/growth phase	< 24 hours	
Source of organisms	Laboratory culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	48 hr	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	0 %	
Temperature	20-21 ^{o}C	
Test type	Flow-through	
Photoperiod/light intensity	16 light: 8 dark	
Dilution water	EPA hard water (fortified well water)	Warham Mass. well water
pH	7.9-8.3	
Hardness	160-190 mg/L	
Alkalinity	110-130 mg/L	
Conductivity	400-600 uMhos/cm	
Dissolved Oxygen	> 5.6 mg/L	
Feeding	None	

Reference	**Surprenant 1983**	***D. magna***
Parameter	**Value**	**Comment**
Purity of test substance	88.35 %	
Concentrations measured?	No	
Measured is what % of nominal?	NR	
Chemical method documented?	No	
Concentration of carrier (if any) in test solutions	< 0.47 µL/mL	DMF
Concentration 1 Nom (µg/L)	10	4 reps, 20 org/rep
Concentration 2 Nom (µg/L)	5	4 reps, 20 org/rep
Concentration 3 Nom (µg/L)	2.5	4 reps, 20 org/rep
Concentration 4 Nom (µg/L)	1.2	4 reps, 20 org/rep
Concentration 5 Nom (µg/L)	0.60	4 reps, 20 org/rep
Control	Solvent control and dilution water	4 reps, 20 org/rep
LC_{50} (95% confidence limit)	48 hr: 1.6 (1.2-2.0) µg/L	Moving angle average analysis

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Hypothesis tests (3)

Toxicity Data Summary

Daphnia magna

Study: Burgess D. 1989. Chronic Toxicity of 14C-FMC 54800 to Daphnia magna Under Flow-Through Test Conditions. ABC Labs. FMC #A88-2649. MRID 411565-01.

Relevance
Score: 100
Rating: R

Reliability
Score: 93.5
Rating: R

Reference	**Burgess 1989**	***D. magna***
Parameter	**Value**	**Comment**
Test method cited	USEPA/ASTM/ Organization for Economic Cooperation and Development	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*magna*	
Family in North America?	Yes	
Age/size at start of test	< 24 hours	
Source of organisms	Lab Culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated / disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Not Reported	
Test duration	21 Days	
Data for multiple times?	Raw data, but no toxicity values	
Effect 1	Survival	
Control response 1	97.5 %	
Effect 2	Length	
Control response 2	4.1 mm	
Effect 3	Time to 1st Brood	
Control response 3	8 days	
Effect 4	Reproduction	
Control response 4	4.7 young/day/adult	
Temperature	19 – 20 ºC	
Test type	Flow-Through	
Photoperiod/light intensity	16 light:8 dark, 30-70 Foot Candles	
Dilution water	Blended R.O. and well water to achieve hardness	Missouri well water

Reference	**Burgess 1989**	***D. magna***
Parameter	**Value**	**Comment**
pH	7.4-7.7	
Hardness	160-180 mg/L	
Alkalinity	174-192 mg/L	
Conductivity	350-360 µmhos/cm	
Dissolved Oxygen	7.4-8.4 mg/L	
Feeding	Selenastrum suspension 3x daily + Yeast, Vitamin, Tetramin 1x daily	
Purity of test substance	97%	purified in lab
Concentrations measured?	Yes	
Measured is what % of nominal?	50-76%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Not Reported	
Concentration 1 Nom/Meas (ng/L)	0.6/0.296	4 rep/10 per rep
Concentration 2 Nom/Meas (ng/L)	1.2/0.76	4 rep/10 per rep
Concentration 3 Nom/Meas (ng/L)	2.5/1.3	4 rep/10 per rep
Concentration 4 Nom/Meas (ng/L)	5/2.9	4 rep/10 per rep
Concentration 5 Nom/Meas (ng/L)	10/7.6	4 rep/10 per rep
Control/Solvent Control	0/Unreported	4 rep/10 per rep
Reproduction		
NOEC	1.3 ng/L (reproduction)	Method: ANOVA w/Dunnet's test p: 0.05, MSD: NR
LOEC	2.9 ng/L	
MATC (GeoMean NOEC,LOEC)	1.9 ng/L	
% control at NOEC	4.5/4.7 - 96%	
% of control LOEC	2.1/4.7 - 44%	
Length		
NOEC	2.9 ng/L (length)	Method: ANOVA w/Dunnet's test p: 0.05, MSD: NR
LOEC	7.6 ng/L	
MATC (GeoMean NOEC,LOEC)	4.7 ng/L	
% control at NOEC	3.6/4.1 - 88%	
% of control LOEC	3.2/4.1 - 78%	
Time to 1st brood		
NOEC	2.9 ng/L (time to 1st brood)	Method: ANOVA w/Dunnet's test p: .05, MSD: NR
LOEC	7.6 ng/L	
MATC (GeoMean NOEC,LOEC)	4.7 ng/L	
% control at NOEC	NR	
% of control LOEC	NR	

Reliability points taken off for:
Documentation: Minimum significant difference (2)

Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.1 mL/L (4), Random or block design (2), Minimum significant difference (1)

Toxicity Data Summary

Hyalella azteca

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (CA, USA): Relative effects of pesticides and suspended particles. Environmental Pollution 141:402-408.

Relevance
Score: 90 (no Standard method)
Rating: R

Reliability
Score: 79
Rating: R

Reference	**Anderson *et al.* 2006**	***H. azteca***
Parameter	**Value**	**Comment**
Test method cited	NR	
Phylum	Arthropoda	
Class	Crustacea	
Order	Malacostraca	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family in North America?	Yes	
Age/size at start of test/growth phase	7-14 days	
Source of organisms	Aquatic Biosystems, FT. Collins, CO.	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	No	
Test duration	96 hours	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	97% survival*	
Temperature	23 ± 1°C*	
Test type	Static	
Photoperiod/light intensity	16 light: 8 dark*	
Dilution water	Well Water	
pH	NR	
Hardness	91.6 mg/L*	
Alkalinity	122.4 mg/L as CaCO3*	
Conductivity	NR	

Reference	**Anderson *et al.* 2006**	***H. azteca***
Parameter	**Value**	**Comment**
Dissolved Oxygen	NR	
Feeding	Not fed	
Purity of test substance	100%	
Concentrations measured?	Yes	
Measured is what % of nominal?	19-56%	Meas. 2 reps of only some conc's
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Used 100 mg/L methanol stock	
Concentration 1 Nom (µg/L)	0.0056	3 reps, 5 org/rep
Concentration 2 Nom/Meas (µg/L)	0.010/ 0.002, 0.005	3 reps, 5 org/rep
Concentration 3 Nom (µg/L)	0.018	3 reps, 5 org/rep
Concentration 4 Nom/Meas (µg/L)	0.032/ 0.006,0.018	3 reps, 5 org/rep
Concentration 5 Nom (µg/L)	0.056	3 reps, 5 org/rep
Control	0	3 reps, 5 org/rep
LC_{50}	0.0093 µg/L	Method: Spearman-Karber

Other notes:

*Control survival, temp. variation and water chemistry obtained by personal communication with the testing laboratory.

Reliability points taken off for:
Documentation: Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)
Acceptability: Standard method (5), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated (1), Dissolved oxygen (6), Conductivity (1), pH (2), Random / block design (2), Hypothesis tests (3)

Toxicity Data Summary

Hyalella azteca

Study: Weston DP, Jackson CJ. 2009. Use of Engineered Enzymes to Identify Organophosphate and Pyrethroid-Related Toxicity in Toxicity Identification Evaluations. Environmental Science and Technology 43:5514-5520.

Relevance
Score: 100
Rating: R

Reliability
Score: 88
Rating: R

Reference	**Weston & Jackson 2009**	***H. azteca***
Parameter	**Value**	**Comment**
Test method cited	USEPA	Modified for H. azteca
Phylum	Arthropoda	
Class	Crustacea	
Order	Malacostraca	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family in North America?	Yes	
Age/size at start of test/growth phase	7- 14 d†	
Source of organisms	Lab Culture†	Weston lab
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes†	
Animals randomized?	Yes†	
Test vessels randomized?	Yes†	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	Median control survival was 95% (range 84-100%). Median solvent control survival for the acetone carrier was 98% (84-100%)	
Effect 2	Impaired swimming*	
Control response 2	Survivors never had impaired control response	
Temperature	23 °C	
Test type	Static renewal (48 h)	
Photoperiod/light intensity	16:8 (light:dark)	
Dilution water	EPA moderately hard water,	

Reference	**Weston & Jackson 2009**	***H. azteca***
Parameter	**Value**	**Comment**
	from purified water	
pH	7.5†	
Hardness	90 mg/L as $CaCO_3$ †	
Alkalinity	60 mg/L as $CaCO_3$ †	
Conductivity	335 umhos/cm†	
Dissolved Oxygen	7.4 mg/L†	
Feeding	Yes, but appropriate	DO depletion & sorption minimized by feeding 6h prior to renewal
Purity of test substance	> 98%†	
Concentrations measured?	One concentration	
Measured is what % of nominal?	median 114% of nominal; range 64-189%	pyrethroid conc. declined to a median of 34% of initial nominal concentration within 48 h (range <12-72%, *n* = 9).
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Acetone, < 32 µL/L	
Concentration 1 Nom/Meas (µg/L)	5-8 conc. separated by a factor of 0.5 (e.g., 20, 10, 5, 2.5, 1.3 ng/L)	3 reps, 10 org /rep †
Control	Solvent	3 reps, 10 org/rep
LC_{50} (95% confidence interval) ng/L	2.7 (2.1-3.3) 7.3 (6.1-8.6) 8.0 (6.8-9.4) 8.2 (7.0-9.6)	Method: Probit
EC_{50} (95% confidence interval) ng/L	1.9 (1.5-2.3) 3.1 (2.7-3.7) 3.5 (3.1-3.9) 3.5 (2.9-4.1)	Probit

Other notes:

†Indicates information was gathered or clarified via email communication with the author Dr. Donald Weston (dweston@berkeley.edu).

*Most impaired organisms were lying on their sides, able only to twitch one or more appendages. For those few individuals still able to swim, movement was poorly coordinated and swimming limited to only a few body lengths. Therefore, we also recorded the proportion of animals able to swim normally, with results reported as the median effective concentration (EC_{50}).

When spiking water or sediment with pesticides, samples to determine the actual pesticide concentration were taken from one concentration step in the midpoint of the range used. For the water tests, the initial water concentration was determined at time 0 and again when fresh solutions were prepared at 48 h. The two samples were either analyzed separately or as a composite. Samples were also taken of water that had been in the beakers for the maximum period (at the end of the first and second 48 h intervals, combined as a composite).

The average pyrethroid concentrations to which *H. azteca* were exposed were approximated as the nominal concentration minus one-half of the 66% nonenzymatic loss over 48 h (i.e., average actual concentration equal to 33% less than nominal). All reported water concentrations are actual values, derived from nominal concentrations adjusted by this factor.

Reliability points taken off for:
Documentation: Nominal concentrations (3), Measured concentrations (3), Hypothesis tests (8)
Acceptability: Meas. conc. w/in 20% of nom. (4), Conc. not > 2x water solubility (4), Hypothesis tests (3)

Toxicity Data Summary

Lepomis macrochirus

Study: Hoberg JR. 1983a. Acute toxicity of FMC 54800 technical to bluegill (*Lepomis macrochirus*). FMC Study No: A83/987. MRID 00132536.

Relevance
Score: 100
Rating: R

Reliability
Score: 84.5
Rating: R

Reference	**Hoberg 1983a**	***L. macrochirus***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Chordata	
Class	Actinopterygii	
Order	Perciformes	
Family	Centrarchidae	
Genus	*Lepomis*	
Species	*macrochirus*	
Native to	St. Lawrence River, Great Lakes, Mississippi River	Introduced worldwide
Age/size at start of test/growth phase	2.5 (1.3-3.6) g 58 (49-64) mm	mean (range)
Source of organisms	Commercial supplier	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	14 day acclimation period
Animals randomized?	No	
Test vessels randomized?	No	
Test duration	144 hr	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	0 % at all time points	
Temperature	21-22 ^{o}C	
Test type	Flow though	
Photoperiod/light intensity	16 light:8 dark (2-20 hectolux)	
Dilution water	Well water	
pH	7.0-7.5	
Hardness	28-30 mg/L	
Alkalinity	24-28 mg/L	
Conductivity	100-140 µMhos/cm	
Dissolved Oxygen	87-94% saturation	

Reference	**Hoberg 1983a**	***L. macrochirus***
Parameter	**Value**	**Comment**
Feeding	Dry pelleted food @ 120 hr	ad libitum
Purity of test substance	88.35 %	
Concentrations measured?	No	
Measured is what % of nominal?	n/a	
Chemical method documented?	No	
Concentration of carrier (if any) in test solutions	NR	DMF
Concentration 1 Nom (µg/L)	1	2 reps /10 fish each
Concentration 2 Nom (µg/L)	0.65	2 reps /10 fish each
Concentration 3 Nom (µg/L)	0.42	2 reps /10 fish each
Concentration 4 Nom (µg/L)	0.27	2 reps /10 fish each
Concentration 5 Nom (µg/L)	0.18	2 reps /10 fish each
Control	Control and solvent control	
LC_{50} (95% confidence interval)	48 hr: 0.65 (0.42-1.0) µg/L	Method: Binomial probability
LC_{50} (95% confidence interval)	72 hr: 0.44 (0.39-0.50) µg/L 96 hr: 0.35 (0.30-0.40) µg/L 144 hr: 0.30 (0.28-0.35) µg/L	Method: Moving angle average

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Organisms randomly assigned to containers (1), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

*Onchorynchus mykiss (*formerly *Salmo gairdneri)*

Study: Hoberg JR. 1983b. Acute toxicity of FMC 54800 technical to rainbow trout (*Salmo gairdneri*). FMC Study No: A83/967. MRID 00132539.

Relevance
Score: 100
Rating: R

Reliability
Score: 86
Rating: R

Reference	**Hoberg 1983b**	***O. mykiss***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Vertebrae	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	*Oncorhynchus*	
Species	*mykiss*	
Native to	Canada, Alaska	
Age/size at start of test/growth phase	1.0 (0.57-1.6) g 46 (40-54) mm	mean (range)
Source of organisms	Commercial supplier	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Not reported	
Test vessels randomized?	Not reported	
Test duration	120 hr	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	0% (at all times)	
Temperature	11 - 12 ^{o}C	
Test type	Flow-through	
Photoperiod/light intensity	16 light :8 dark	
Dilution water	Well water	
pH	7.0 - 7.3	
Hardness	28-30 mg/L	
Alkalinity	24 mg/L as $CaCO_3$	
Conductivity	130-140 µMhos/cm	
Dissolved Oxygen	9.0 - 9.8 mg/L	
Feeding	None	
Purity of test substance	88.35 %	

Reference	**Hoberg 1983b**	***O. mykiss***
Parameter	**Value**	**Comment**
Concentrations measured?	No	
Measured is what % of nominal?	Not applicable	
Chemical method documented?	Not applicable	
Concentration of carrier (if any) in test solutions	Not reported	Dimethyl formamide (DMF)
Concentration 1 Nom (µg/L)	1.5	2 reps /10 fish each
Concentration 2 Nom (µg/L)	0.75	2 reps /10 fish each
Concentration 3 Nom (µg/L)	0.38	2 reps /10 fish each
Concentration 4 Nom (µg/L)	0.19	2 reps /10 fish each
Concentration 5 Nom (µg/L)	0.094	2 reps /10 fish each
Control	Control and solvent control	2 reps /10 fish each
LC_{50}	24 h: 6.2 µg/L	Method: probit analysis
LC_{50} (95% confidence interval)	48 h: 0.34 (0.27-0.42) µg/L 72 h: 0.20 (0.15-0.26) µg/L 96 h: 0.15 (0.15-0.26) µg/L 120 h: 0.10 (0.15-0.26) µg/L	Method: moving angle average analysis

Other notes:

- Increased mortalities prevented calculation of an LC50 after 120hrs
- Moving angle average analysis:
  Peltier, W.H., and Weber, C.I. (1985). *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms.* EPA-600/4-85-013, U.S. Environmental Protection Agency, Cincinnati, OH.

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Hypothesis tests (8)
Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Pimephales promelas

Study: Guy D. 2000b. Aquatic Toxicology laboratory Report P-2161-2. Bifenthrin with *Pimephales promelas* in an acute definitive test. California Department of Fish and Game, Aquatic Toxicology Lab, Elk Grove, CA.

Relevance
Score: 100
Rating: R

Reliability
Score: 85
Rating: R

Reference	**Guy 2000b**	***P. promelas***
Parameter	**Value**	**Comment**
Test method cited	ASTM /EPA	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family in North America?	Yes	
Age/size at start of test/growth phase	8 d, dry wt: 0.0039-0.0052 g	
Source of organisms	Aquatic Resources Lab	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	100% in solvent control; 98% in dilution water cont	
Temperature	24.0 - 24.5 ^{o}C	
Test type	Static w/ 48 h renewal	
Photoperiod/light intensity	16:8 light:dark	
Dilution water	NR	
pH	8.02-8.41	
Hardness	150-162 mg/L	
Alkalinity	170-182 mg/L	
Conductivity	328-447 µs/cm	
Dissolved Oxygen	6.65-8.33 mg/L	

Reference	**Guy 2000b**	***P. promelas***
Parameter	**Value**	**Comment**
Feeding	Yes, can not determine if during test or just acclimation period	
Purity of test substance	97.8%	
Concentrations measured?	Not directly: estimated	
Measured is what % of nominal?	184 - 204% estimated from spikes	
Chemical method documented?	No (would be helpful to know since recovery abnormally high)	
Concentration of carrier (if any) in test solutions	0.0055 mL/L (acetone)	
Nominal and estimated (Est) concentrations (divided by a factor derived from recovery of spiked water samples on day 0 and day 2		
Concentration 1 Nom/Est (µg/L)	0.3/0.56	4 reps; 10 fish per rep
Concentration 2 Nom/Est (µg/L)	0.6/1.09	4 reps; 10 fish per rep
Concentration 3 Nom/Est (µg/L)	1.25/2.4	4 reps; 10 fish per rep
Concentration 4 Nom/Est (µg/L)	2.5/5.1	4 reps; 10 fish per rep
Concentration 5 Nom/Est (µg/L)	3.75/7.40	4 reps; 10 fish per rep
Concentration 6 Nom/Est (µg/L)	5 /9.18	4 reps; 10 fish per rep
Controls	Water only and a solvent (acetone) control	4 reps; 10 fish per rep
LC_{50} (95% confidence interval)	0.78 (0.526-0.853) µg/L	Method: Linear interpolation

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Dilution water source (3), Hypothesis tests (8)
Acceptability: Measured concentrations within 20% nominal (4), Organism fed in acute tests (3), Dilution water source acceptable (2), Hypothesis tests (3)

Toxicity Data Summary

Pimephales promelas

Study: McAllister WA. 1988. Full life cycle toxicity of ^{14}C-FMC 54800 to the fathead minnow (*Pimphales promelas*) in a flow-through system. FMC Study No: A86/2100. MRID 40791301.

Relevance
Score: 100
Rating: R

Reliability
Score: chronic 93.5, acute 87.5
Rating: R

Reference	**McAllister 1988**	***P. promelas***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Native to	North America	
Age/size at start of test/growth phase	Chronic: < 48 hr eggs Acute: 14 d old	
Source of organisms	In-house laboratory culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	Chronic: 368 days Acute: 96 h	F_0 and F_1 gen - entire life cycle
Data for multiple times?	Yes	
Acute effect 1	96 h Mortality	
Acute control response 1	0%	
Chronic effect 1	92 d F_0 Survival	
Control response 1	100%	
Effect 2-6	Number eggs / female, Number of spawns, Number of eggs, Number spawns / female, Number eggs / female, Percent egg hatch	No statistically significant responses, but trend - High variability, See Fig. 10
Other effects measured	F_0 wet weight, F_0 Hatchability, F_0 Standard length, F_1 Hatchability, F_1	No statistically significant responses found

Reference	**McAllister 1988**	***P. promelas***
Parameter	**Value**	**Comment**
	Standard length, F_1 wet weight, F_1 wet weight, F_1 Survival	
Other Effect/ info in study	Bioconcentration factor	
	> 48 hr old 83-4900X	
	96 hr old 530-10,000X	
	14 day old 6000X	0.019 µg/L conc.
	Whole body residue Adults (F_0) 21-28,000X	
Temperature	25 ± 1 °C	
Test type	Acute: static Chronic: flow-through	
Photoperiod/light intensity	Chronic: 16 light: 8 dark Acute: NR	
Dilution water	Aerated well water	
pH	Chronic: 7.8 - 8.2 Acute: 8.1-8.2	
Hardness	Chronic: 246 - 346 mg/L Acute: 270-280 mg/L	
Alkalinity	Chronic: 302 - 522 mg/L Acute: NR	
Conductivity	Chronic: 530 – 840 uMhos/cm Acute: NR	
Dissolved Oxygen	Chronic: 3.9 - 8.7 mg/L Acute: 5.2-8.7 mg/L	
Feeding	Acute - none Chronic - daily artemia	
Purity of test substance	Technical- 96.2%	^{14}C labeled
Concentrations measured? (ug/L)	Yes	
Measured is what % of nominal?	Acute: 73-88% Chronic: 53 - 146 %	
Chemical method documented?	Liquid scintillation counting	
Concentration of carrier (if any) in test solutions	max. 0.013 mL/L	Acetone
Acute test		
Concentration 1 Nom/Meas (µg/L)	0.051/0.042	10 fish per aquaria
Concentration 2 Nom/Meas (µg/L)	0.10/0.083	10 fish per aquaria
Concentration 3 Nom/Meas (µg/L)	0.20/0.17	10 fish per aquaria
Concentration 4 Nom/Meas (µg/L)	0.40/0.35	10 fish per aquaria
Concentration 5 Nom/Meas (µg/L)	0.80/0.58	10 fish per aquaria
Control	Water only + solvent	10 fish per aquaria
LC_{50} (95% confidence interval)	96 hr: 0.21 (0.16-0.28) µg/L	Method: Moving

Reference	**McAllister 1988**	***P. promelas***
Parameter	**Value**	**Comment**
		average
Chronic		
Concentration 1 Nom/Meas (µg/L)	0.0050/0.0037 ± 0.0013	Started w/ 35 eggs in 4 replicate chambers at each conc. (was F_0)
Concentration 2 Nom/Meas (µg/L)	0.0090/0.0090 ± 0.0034	
Concentration 3 Nom/Meas (µg/L)	0.019/0.019 ± 0.0062	
Concentration 4 Nom/Meas (µg/L)	0.038/0.040 ± 0.017	
Concentration 5 Nom/Meas (µg/L)	0.075/0.090 ± 0.042	
Control	Water only + solvent (acetone)	
Chronic 92 d F_0 Survival		
NOEC	0.040 µg/L	Method: ANOVA w/ Tukey's HSD p: 0.05 MSD: NR
LOEC	0.090 µg/L	
MATC (GeoMean NOEC,LOEC)	0.060 µg/L	
% of control at NOEC	Day 92: 100%	
% of control LOEC	Day 92: 54%	

Static acute tests are not good for calculating ACR for fish

Acute and chronic test run separately. Acute test is static, and is documented separately at starting on pg 168.

Reliability points taken off CHRONIC test for:
Documentation: Minimum significant difference (MSD)(2).
Acceptability: Measured concentrations within 20% Nom (4), Dissolved oxygen ≥ 60 % (6), MSD (1).

Reliability points taken off ACUTE test for:
Documentation: Alkalinity (2), Conductivity (2), Photoperiod (3), Minimum significant difference (MSD)(2).
Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Alkalinity (2), Conductivity (1), Photoperiod (2), Adequate replication (2), MSD (1).

Toxicity Data Summary

Procloeon sp.

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (CA, USA): Relative effects of pesticides and suspended particles. Environmental Pollution 141:402-408.

Relevance
Score: 90 (no Std method)
Rating: R

Reliability
Score: 77
Rating: R

Reference	**Anderson *et al.* 2006**	***Procloeon sp.***
Parameter	**Value**	**Comment**
Test method cited	NR	
Phylum	Arthropoda	
Class	Insecta	
Order	Ephemeroptera	
Family	Baetidae	
Genus	*Procloeon*	
Species	NR	
Family in North America?	Yes	
Age/size at start of test/growth phase	0.5-1.0 cm	
Source of organisms	Reference station, Salinas River	
Have organisms been exposed to contaminants?	Maybe	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	No	
Test duration	48 hours	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	87% survival*	
Temperature	23 ± 1°C *	
Test type	Static	
Photoperiod/light intensity	16 light: 8 dark*	
Dilution water	Well Water	
pH	NR	
Hardness	91.6 mg/L*	
Alkalinity	122.4 mg/L as CaCO3*	
Conductivity	NR	

Reference	**Anderson *et al.* 2006**	***Procloeon sp.***
Parameter	**Value**	**Comment**
Dissolved Oxygen	NR	
Feeding	Not fed	
Purity of test substance	100%	
Concentrations measured?	Yes	
Measured is what % of nominal?	55-77%	Meas. 2 reps of only some conc's
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Used 100 mg/L methanol stock	
Concentration 1 Nom (µg/L)	0.018	3 reps, 5 org/rep
Concentration 2 Nom (µg/L)	0.032	3 reps, 5 org/rep
Concentration 3 Nom/Meas) (µg/L)	0.056/0.031, 0.043	3 reps, 5 org/rep
Concentration 4 Nom (µg/L)	0.100	3 reps, 5 org/rep
Concentration 5 Nom (µg/L)	0.180	3 reps, 5 org/rep
Concentration 6 Nom/Meas (µg/L)	0.320/0.206, 0.202	3 reps, 5 org/rep
Concentration 7 Nom (µg/L)	0.560	3 reps, 5 org/rep
Control	0	3 reps, 5 org/rep
LC_{50}	0.084 µg/L	Method: Spearman-Karber

Other notes:

*Control survival, temp. variation and water chemistry obtained by personal communication with the testing laboratory.

Reliability points taken off for:
Documentation: Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)
Acceptability: Standard method (5), Measured concentrations within 20% nominal (4), Organisms randomly assigned to containers (1), Organisms properly acclimated (1), Dissolved oxygen (6), Conductivity (1), pH (2), Random / block design (2), Hypothesis tests (3), prior contaminant exposure? (4)

Appendix B

Fit test calculations

Raw data and calculations for fit test for bifenthrin acute data

Bifenthrin all LC 50s	Omit one 1	2	3	4	5	6	7	8
0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.079
0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.0843	0.0843
0.0843	0.0843	0.0843	0.0843	0.0843	0.0843	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.21	0.21	0.21	0.21
0.21	0.21	0.21	0.21	0.35	0.35	0.35	0.35	0.35
0.35	0.35	0.35	1.6	1.6	1.6	1.6	1.6	1.6
1.6	1.6	26.15	26.15	26.15	26.15	26.15	26.15	26.15
2.62								
Omitted point, xi:	2.62	1.6	0.35	0.21	0.15	0.0843	0.079	0.0065
5th percentile 0.00373	0.00351	0.00305	0.00269	0.00272	0.00303	0.00348	0.00356	0.01529
Log logistic Distribution								
F-i(xi)	94.22	89.098	64.9767	61.749	42.194	29.558	27.97	0.7954
	0.9422	0.89098	0.64977	0.61749	0.42194	0.29558	0.2797	0.00795
1-F(xi)	0.0578	0.10902	0.35023	0.38251	0.57806	0.70442	0.7203	0.99205
Min of F-i(xi) or 1-F(xi)	0.0578	0.10902	0.35023	0.38251	0.42194	0.29558	0.2797	0.00795
pi =2(min)	0.1156	0.21804	0.70047	0.76502	0.84388	0.59116	0.5594	0.01591

Raw data and calculations for fit test for bifenthrin acute data (continued)

	Fisher test statistic		
pi-values	ln(pi-value)	Sum of ln (pi)	X^2_{2n}
0.1156	-2.1576	19.4436	0.2463
0.2180	-1.5231		
0.7005	-0.3560		
0.7650	-0.2679		
0.8439	-0.1697		
0.5912	-0.5257		
0.5594	-0.5809		
0.0159	-4.1409		

0.25 is > 0.05 so the distribution fits the bifenthrin acute data set

if $p < 0.05$ significant lack of fit
if $p > 0.05$ fit (no significant lack of fit)